Undergraduate Research Abstract

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Note

Cocoro Wachi is an undergraduate student in computer science interested in addressing civil engineering problems.

Background

Modeling sewer hydrology, specifically wet weather flow into sanitary sewer systems, is difficult. Sanitary sewers are designed and built specifically to exclude rainfall-derived and groundwater infiltration and inflow. Yet, it occurs. Too much wet weather flow causes basement backups and overflows of raw sewage into waterways. When this occurs, wastewater utilities must repair or replace their infrastructure. The 2021 ASCE Infrastructure Report Card reports that wastewater utilities throughout the US spent more than $3 billion on wastewater pipe repairs and replacements in 2020. Wise decisions on where and how to improve sanitary sewer infrastructure requires accurate sewer hydrology models.

In an effort to improve the sewer hydrology modeling, Czachorski and Van Pelt in 2001 introduced a system identification approach for modeling wet weather flow into sanitary sewer systems. What was innovative in this approach was using a temperature signal to represent the seasonally varying response to rainfall. The approach tracked antecedent moisture which impacted the wet weather response of a sanitary sewer system to a rainfall event. The uses three transfer functions: the temperature factor transfer function, the antecedent moisture transfer function, and the linear rainfall-runoff transfer function. Czachorski used this approach for many years modeling hundreds of sanitary sewer systems.

In 2022, Czachorski published the details of the algorithm. Previously it had been guarded as a trade secret. This paper contains the details of the original Czachorski and Van Pelt system identification approach. In 2024, Edgren, Czachorski and Gonwa presented a reparameterization of the antecedent moisture model, which left the model with three transfer functions (levels), but converted the parameters to ones that had better physical significance and created time-step independence of the parameters.

In 2023, Alex Luedke, under the direction of Dr. Gonwa, completed an MSOE master's capstone project where he looked at using stream gages to represent antecedent moisture conditions in the antecedent moisture model. Luedke not only looked at using streamflow as a direct replacement for temperature, he developed a two-level method in which scaled streamflow replaced both the temperature and antecedent moisture transfer functions. Edgren in 2023 conducted a numerical comparison of sewer infiltration models that compared the ability of Luedke and Gonwa's two-level method, the original three-level method, and a number of other methods to accurately predict wet weather flow in sanitary sewers. He compared predictions at 10 sites using 975 identified rain events. Edgren found that the two-level method "showed well for such an untested model" and concluded that it was a promising approach and merited further research.

Research Proposal

This research will perform further testing and development of the two-level sewer hydrology model developed by Luedke and Gonwa, as recommended by Edgren. Since the two-level model is basically a signal processor, it provides a valuable opportunity for inserting expertise in computer science into the discipline of civil engineering.

The research will use data provided by the Milwaukee Metropolitan Sewerage District (MMSD) which operates long-term sewer flow meters and rain gages throughout the metropolitan area. MSOE has a good working relationship with MMSD and has obtained long-term data from MMSD several times. Streamflow data is available for download for numerous locations from the United States Geological Survey (USGS).

Specific research activities will include:

- Developing code to process raw data from MMSD and the USGS
- Developing an algorithm and code to remove the daily variation in sewer flow caused by human activities (diurnal variation in dry weather flow)
- Developing an algorithm and code to separate out long-term variation in baseflow caused by groundwater variations (use a Lynn-Hollick filter or other appropriate method)
- Isolating the wet weather flow signal by subtracting the diurnal variation in dry weather flow and long-term variation in baseflow from the total flow
- Developing code to replicate Luedke's Capstone modeling, which was performed in Excel (this involves two parallel models, one to replicate a fast response and the other to replicate a slow response)
- Implement metrics to measure the goodness-of-fit of the model to wet weather flow signal (see Edgren 2023 metrics)

- Developing code to automatically optimize model parameters
- Test the viability of using wastewater treatment plant inflow as an alternative indicator of antecedent moisture
- Explore other possibilities for improving the model form as become evident during the course of testing
- Explore the possibility of AI assistance in improving the models or determining the optimal parameters

Course Credit and Advisor

I envision a three-credit undergraduate research course followed by an option for a second three-credit undergraduate course. The computer science program director would need to assess whether the work would qualify as a computer science technical elective. It is possible that the undergraduate research morph into the senior capstone project.

Dr. Gonwa is a subject matter expert on sewer hydrology modeling. It may be appropriate to add an additional advisor in computer science or signal processing.

Research Output

There are several appropriate venues for presenting or publishing the results of the research:

- Water Environment Federation Technology and Exposition Conference (WEFTEC)
- Water Environment Federation Collection Systems Conference
- Environmental and Water Resources Institute World Congress
- International Conference on Water Management Modeling
- Journal of Water Management Modeling

References

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